

*SOME QUESTIONS ABOUT UNIFICATION OF
CONDITIONING PROCESSES, STIMULUS-RESPONSE PSYCHOLOGY, AND
NEURAL NETWORK MODELS*

STEVEN I. DWORKIN AND MARC N. BRANCH

BOWMAN GRAY SCHOOL OF MEDICINE AND
UNIVERSITY OF FLORIDA

Donahoe, Palmer, and Burgos have provided a stimulating, provocative viewpoint on conditioning processes. We are especially appreciative of the clear and compelling way in which they characterize behavioral science as historical science. It seems undeniable that behavior at any moment is a result of a cumulation of actions of simpler processes across time and that, therefore, complex human behavior is resistant to experimental analysis. They suggest that neural network models exemplify the process of cumulation and therefore may serve well as models of conditioning processes. Their paper generated many questions for us, far more than can be accommodated in a short commentary. We, nevertheless, would like to pose a few so that Donahoe et al. can illuminate their position more fully.

Our first question has to do with the treatment of operant and respondent conditioning processes as unified. It is not fully clear to us what exactly the word *unified* means as employed by Donahoe et al. If it means that conditioning arrangements invariably allow for both processes to operate, that is one thing. If it means that there is only a single conditioning process, that is another. It is our view that what is known currently makes it difficult to conceive of the two conditioning processes really as different manifestations of a single one. Consider first how characteristics of an unconditional stimulus (US) can alter what transpires in a conditioning situation. Because respondent conditioning inevitably can accompany operant conditioning, let us examine the case of a discriminat-

ed operant. A discriminative stimulus (S^D) precedes a selected class, R, of arbitrary actions, which in turn is followed by a reinforcer (S^R) that also may be considered to be a US that elicits a particular unconditional response (UR). Experiencing this sequence not only makes R more likely to occur when the S^D is presented; it also establishes the S^D as a conditional stimulus (CS) that elicits a response similar in form to the UR (Eikelboom & Stewart, 1982). For example, if the US is food, then the CS (S^D) will elicit salivation. Thus, two things happen: The probability of R increases, and the probability that the S^D (CS) will elicit salivation increases too. By contrast, consider what occurs if the US is a painful electric shock. If we arrange the same contingency, the result is that what we normally consider to be respondent conditioning will proceed as before. That is, the CS (S^D) will come to elicit a response (or responses) similar in form to that (those) elicited by the US. This result is exactly analogous to what happens with food as a US. What happens to the class of actions, R, however, is not the same. In this case, the probability of R decreases (the process is known as punishment). It is difficult for us to reconcile the differences in outcomes with the operant response and the elicited response with the notion that a single conditioning process is operating. Conceptualizing the elicitation of the respondent as representing a conditioning process distinct from that which alters the probability of the operant makes it easy to understand the differences in outcome. How does a unified process make it simple to understand?

A second difference between operant and respondent conditioning also needs to be considered when looking for an account that unifies conditioning processes. That difference lies in the nature of the responses that

Preparation of this paper was supported by USPHS Grants DA04074, DA03628, and DA06634.

Reprints may be obtained from either author: Steven I. Dworkin, Department of Physiology and Pharmacology, Bowman Gray School of Medicine, Winston-Salem, North Carolina 27157, or Marc Branch, Psychology Department, University of Florida, Gainesville, Florida 32611.

are conditioned. It is still true that no reliable evidence exists that visceral responses can be conditioned via operant methods (Dworkin & Miller, 1986), whereas there is ample evidence that such responses can participate in respondent conditioning (e.g., Mazur, 1990). It is not clear to us how a unification of processes can incorporate this difference, so we look to Donahoe et al. for assistance.

As we understand neural network models, they rely on back-propagation to alter the state of the network, yet these models seem to be silent on details about how the propagation emerges or on how it may vary. Consider the following. There appear to be at least three ways by which environmental stimuli come to be effective in selecting consequences for arbitrarily chosen actions. The first is to serve as a reinforcer prior to being exposed to any type of deprivation or establishing procedures. Thus, a specific history of the subject with regard to specific environmental conditions is unnecessary for these stimuli to serve as reinforcers. For example, intravenous administration of cocaine or heroin can reinforce behavior prior to any previous exposure to those substances. Stimuli may also acquire reinforcing effects as a result of deprivation or other establishing operations. For example, development of both oral ethanol and cocaine self-administration requires some type of establishing operation (e.g., schedule induction or sucrose fading), although genetic manipulations can result in strains of rats and mice that may be more susceptible to the reinforcing effects of these compounds (Crabbe & Belknap, 1992). A third type of environmental stimulus acquires reinforcing effects only after repeated pairings with the other two types of stimuli and loses the ability to serve as a reinforcer when it is just as likely to occur in the absence as in the presence of the paired stimulus. Stimuli of this type usually are referred to as conditioned reinforcers (Mazur, 1990). Not only do effective reinforcers differ in their provenance, they can also differ in efficacy. One of the most controversial questions in recent neurobehavioral pharmacology is the specific role of dopamine in behavioral processes related to reinforcement. Some neuroscientists have suggested that dopamine is involved in modulating the reinforcing efficacy of reinforcers, whereas others have suggested that

dopamine is involved in modulating the salience of sensory stimuli. It is difficult to discern how the network presented in Donahoe et al.'s Figure 2 can model or account for the differences just described. Is it part of the model to be able to make such distinctions? Should it be, and if so, how might it be accomplished?

A major part of Donahoe et al.'s treatise concerns the roles of stimuli in accounts of conditioning. We have some small questions about their treatment. (a) How does the view propounded by Donahoe et al. mesh with the notion that stimuli, in a behavioristic analysis, are defined functionally (cf. Skinner, 1935)? (b) Is it fair to say that in a free-operant paradigm stimulus effects are effectively camouflaged? The neural network account suggested by Donahoe et al. involves multiple input units, all or some number of which are activated by the conditioning context, but Donahoe et al. seem to argue that the input units ought not to be seen to be isomorphic with features of the environment. That is, they appear to suggest that the input units, because they are models of physiology, have no fixed relation to aspects of the environment. If so, to what do the units respond (i.e., what activates them)? It seems that Donahoe et al.'s view has a good bit in common with stimulus-sampling theory (cf. Bower & Hilgard, 1981, chap. 8), a theory that clearly falls in the stimulus-response theory domain. (b) What does the following easily demonstrable result imply about control by context? Train a food-deprived pigeon to peck a white key by any of the common means (shaping, autoshaping, free-operant acquisition, etc.), and once pecking is occurring steadily, change the color of the key to green. The pigeon will stop pecking immediately. In fact, if you change the key color at just the right time you can stop the pigeon midpeck.

Another thrust of the presentation by Donahoe et al. is an emphasis on moment-to-moment analyses of performance and the importance of momentary conjunctions in the subsequent control of behavior. We have several questions for the authors regarding this focus. (a) It is true that Ferster and Skinner (1957) emphasized the importance of momentary conjunctions in their interpretations of schedule-controlled behavior. Subsequently, however, it has been noted by many (e.g.,

Jenkins, 1970; Zeiler, 1984) that attempts to analyze schedule-controlled behavior on the basis of what occurs temporally near reinforcement have been singularly unsuccessful. Perhaps Donahoe et al. can inform us why those attempts have not been more fruitful. (b) It would also be very illuminating if Donahoe et al. would provide an account of avoidance learning based on close temporal conjunctions between behavior and consequences. That has always proved to be a very difficult task (cf. Hineline, 1977).

Finally, we have three technical questions about the model, or about neural network models in general. (a) Why is conditioning so slow in the model? It certainly is not in the laboratory (cf. Skinner, 1938). As the authors note, "behavior does not fully constrain biology" (p. 197). Nor, given the history of psychological theorizing, does it appear to constrain model and theory building. Physiological theorizing must be constrained by what is known about physiology, so our last two questions bear on that issue. (b) A second concern with the model is how consistent it is with evidence from recent advances in the field of behavioral neuroscience. Recent technological advances have resulted in the in vivo assessment of neurochemical and neurophysiological events that occur during behavioral procedures. These techniques include neuroimaging, measurement of neurotransmitter utilization, microdialysis, and electrophysiological recording. These techniques have greatly increased our knowledge of the complexity of brain mechanisms that are associated with responding maintained by the delivery of contingent events. Neuroimaging techniques have provided a gross as-

essment of the numerous areas of the brain that are involved with the reinforcing effects of environmental events. Given that modern imaging techniques indicate that the number of neurons involved in even the simplest operant behavior is at least 105, how is it that a model with orders of magnitude fewer neurons can be expected to serve adequately? (c) Conversely, what happens as the number of units in each layer of a neural network model is increased?

REFERENCES

- Bower, G. H., & Hilgard, E. R. (1981). *Theories of learning* (5th ed.). Englewood Cliffs, NJ: Prentice Hall.
- Crabbe, J. C., & Belknap, J. K. (1992). Genetic approaches to drug dependence. *Trends in Pharmacological Sciences*, 13, 212-220.
- Dworkin, B. R., & Miller, N. E. (1986). Failure to replicate visceral learning in the acute curarized rat preparation. *Behavioral Neuroscience*, 100, 299-314.
- Eikelboom, R., & Stewart, J. (1982). Conditioning of drug-induced physiological responses. *Psychological Review*, 89, 507-528.
- Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement*. New York: Appleton-Century-Crofts.
- Hineline, P. N. (1977). Negative reinforcement and avoidance. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 364-414). Englewood Cliffs, NJ: Prentice Hall.
- Jenkins, H. M. (1970). Sequential organization in schedules of reinforcement. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules* (pp. 63-109). New York: Appleton-Century-Crofts.
- Mazur, J. (1990). *Learning and behavior* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.
- Skinner, B. F. (1935). The generic nature of the concepts of stimulus and response. *Journal of General Psychology*, 12, 40-65.
- Skinner, B. F. (1938). *The behavior of organisms: An experimental analysis*. New York: Appleton-Century-Crofts.
- Zeiler, M. D. (1984). The sleeping giant: Reinforcement schedules. *Journal of the Experimental Analysis of Behavior*, 42, 485-493.